Frequency of Use and Perceived Effectiveness of Three Simulation Models in Surgical Resident Education

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Abstract

This study evaluated the frequency and perceived effectiveness of use of three surgical simulators across all disciplines and years of surgical training at one institution. A cross-sectional survey examined specific practices and compared the educational experiences of 150 surgical residents in different training levels and disciplines of surgery at the University of Alberta. Resident's exposure to box trainers, virtual reality trainers and simulated patients were analyzed with both open and close ended questions. Eighty-eight of 150 (59%) residents participated and reported use of these surgical simulators varied by year and discipline of training. Fifty percent of respondents used box trainers in their surgical education, with box trainers used most within urology. Generally, there was limited use reported with virtual reality trainers and simulated patients (10% of respondents respectively). Use of both virtual reality trainers and simulated patients was reportedly greatest within ophthalmology. Despite this limited use, residents found a marked and significant correlation (r_S=0.78; p=0.02) between frequency of use and perceived effectiveness of virtual reality models as a method of teaching surgical skills. A marked degree of correlation (r_S=0.65, p=0.06) between frequency of exposure and effectiveness was also found with simulated patient models with a trend towards significance. Modern surgical training is a complex process of cognitive and psychomotor skills training. Use of surgical simulators is expanding, and as more experience and understanding is gained in surgical education, enhanced teaching methods will ultimately produce better skilled surgeons.

Keywords

Surgical Education; Simulation; Box Trainer; Virtual Reality Trainer Model; Simulated Patient Model; Medical Education

Introduction

Since ancient times, the axiom of "see one, do one, teach one" has permeated the culture of surgical education. A surgical trainee watches as a task is demonstrated, then performs the task with supervision prior to teaching it to someone else in turn. This age-old method of instruction is no longer accepted unquestionably. As surgical techniques and technology continue to expand there are a greater number of procedures to master prior to graduation. New regulations also limit the number of consecutive hours residents are permitted to work, thus potentially limiting their experience. Moreover, patients being treated in tertiary academic centers tend to have more complex diseases, frequently rendering teaching opportunities to less experienced junior trainees inappropriate. Increasingly, patients are unwilling to be treated by novice surgeons even under direct supervision, as reflected by increasing litigation against surgeons.[1-4] Subsequently, alternatives to living patient models for surgical instruction are being devised and often implemented into surgical training programs.

Studies abound within the literature postulating, testing and reaffirming various theories of skill acquisition,[2, 5-7] and educators are becoming more knowledgeable in the process of learning motor skills. More nebulous, however, are the methods of transmitting these skills. There has been a recent increase in scholarly interest in the methodologies best suited to instruct surgical trainees. Given the restrictions previously described - increasing litigation, diminished work hours, and an ever growing range of skills to master, it is not surprising that there is a rapid expansion of interest in this burgeoning area.

Historically, surgical expertise was developed using

animal and cadaveric specimens as well as living patient models. Animal models, however, are becoming prohibitively expensive, difficult to access, and are increasingly being more scrutinized for their ethical use in teaching.[2, 3, 8] Subsequently, alternatives are being sought. Some alternatives under investigation include box trainers, virtual reality simulators, and patient simulators. Box trainers are boxes equipped with video equipment and surgical instruments to provide a representation of the abdominal, nasal, or other body cavities while trainees proceed through a variety of technical drills. Virtual reality simulators digitally enhance the box trainers and often provide some feedback to the trainee as well as providing objective assessment of speed, accuracy and precision of skill performance. Patient simulators are enhanced virtual reality models with representative surgical anatomy that responds to manipulation and provides sensory feedback to the trainee, the nuances of which further enhance the surgical experience. Aggarwal and Darzi predicted that, in the near future, surgeons will be able to perform "virtual surgery" in digital environments perfectly mimicking their living patients in the ultimate "dress rehearsal" of the procedure.[9] Future adaptations of this "virtual surgery" may include computerized or artificial intelligence that would intervene during the surgery on its own accord.[9]

In an era where surgical simulation is being promoted as a necessary innovation,[1] the question remains as to whether there is an extensive use of these simulators within surgical training programs and whether these are viable teaching options. To address the issue of surgical skill instruction, the frequency of use of three surgical simulators across all disciplines and years of surgical training at one institution as well as how effective surgical residents perceived these instructional models to be was investigated.

Methods

Questionnaire Development

To answer the study objectives, a cross-sectional, group administered survey examined specific practices and compared educational experiences between different training levels and disciplines of surgery. A questionnaire with both focused open-ended and close-ended questions was developed. The qualitative responses from the open-ended questions permitted content analysis and the close-ended, Likert-styled questions quantified the frequency and perceived efficacy of each method used in surgical instruction. In order to generate a large sample size that could be extrapolated to represent surgical training programs across Canada and beyond, the questionnaire polled as many residents as possible. Initially the questionnaire was piloted to several staff surgeons at outside institutions prior to its presentation to the target population to ensure the questionnaire was effective for evaluation of the central question of surgical skills instruction. The final questionnaire reflected the intent of the study questions; it was concise, unambiguous and capable of eliciting information relevant to the purpose of the study. In order to avoid a biased study population, those who piloted the questionnaire were not part of the target population. This permitted the target population participants to remain "naïve" to survey questions.

Study Population

To determine methods of surgical skill instruction employed at the University of Alberta (U of A), voluntary participants from the 150 surgical residents (spanning all years and disciplines of surgery) registered in all surgical disciplines were recruited. As the total number of surgical residents was relatively small, no surgical sub-specialty was excluded. The selected 150 surgical residents served as a representative sample of surgical residents training in Canada. Recruitment occurred on site at the University of Alberta's affiliated teaching hospitals during an academic half day for each department or division of surgery. Appropriate permission was obtained from the Faculties of Education, Extension and Augustana Research Ethics Board (EEA-REB), the Health Research Ethics Board (Health Panel) – University of Alberta, and the Residency Program Directors and the Chairs of the Departments of Surgery.

Data Management

Responses generated from the close-ended questions on the questionnaire were analyzed using non-parametric Spearman rho (r_S) correlations and two-tailed probability tests to compare two categorical values (Graph Pad Prism 4, GraphPad Software Inc., California, United States of America). The degree of association was based on the five "rules of thumb" developed by Franzblau:[10] "r" values ranging from 0-0.20, 0.2-0.4, 0.4-0.6, 0.6-0.8, and 0.8-1.0 were considered as negligible, low, moderate,

marked, and high degrees of correlation respectively. Open-ended questions were hand-analyzed and coded thematically for each teaching method.

Results

All 150 residents within the target population of surgical subspecialties had the opportunity to participate. Of these, a total of 88 residents completed and returned the survey as illustrated in **Table 1**. The overall survey response rate was 59%. Each instructional method was reviewed for the frequency of exposure to box trainers, virtual reality trainers and simulated patients by both surgical discipline and year of training.

Box Trainer

Fifty percent (44/88) of all responding residents denied ever using box trainers in surgical education, 44% (39/88) reported using this two to three times per year, and 6% (5/88) used box trainer models monthly. **Figure 1** depicts the duration of time residents in each program and year spent using this form of instruction and the level of teaching effectiveness is ranked by both surgical program and year of training. Overall, all 44 participants ranked the effectiveness of this method of instruction. The average rated effectiveness by all respondents was as follows: 25% (11/44) strongly agreed; 50% (22/44) agreed; 23% (10/44) neither

agreed nor disagreed; and 2% (1/44) disagreed that box trainers were effective in teaching surgical skills. No correlation (r_s= - 0.10) was found between frequency of exposure and perceived effectiveness. According to the surveyed responses at this institution, box trainers are used most frequently in urology as compared to other surgical subspecialties. Evaluating the frequency of use by year of residency training, 84% (16/19), 41% (7/17), 50% (11/22), 36% (5/14), 36% (4/11), and 25% (1/4) of participating residents in first, second, third, fourth, fifth and sixth years respectively have experience with box trainers, with seventh year trainee having no experience with this model (0/1). Twenty-seven of the 88 residents recorded comments about what they enjoyed most regarding box trainer models resulting in 29 responses. Sixteen residents supplied 18 comments regarding what they liked least regarding box trainer models used in surgical skills instruction (**Table 2a**).

TABLE 1 RESPONSE RATE BY SURGICAL SUBDIVISION AND YEAR OF TRAINING

Surgical Subdivision	Total Number of Residents	Number of Surveys Completed	Percentage Completed
CV Surgery *	12	5	42
ENT†	10	7	70
General Surgery	40	25	63
Neurosurgery	13	7	54
Obs & Gyne‡	25	15	60
Ophthalmology	10	6	60
Orthopedics	21	12	57
Plastics	11	5	45
Urology	8	6	75
Year of Residency	**Total Number of Residents**	**Number of Surveys Completed**	**Percentage Completed**
1	30	19	63
2	28	17	61
3	32	22	69
4	26	14	54
5	27	11	41
6	6	4	67
7	1	1	100

*CV Surgery is Cardiovascular Surgery, † ENT is Otolaryngology – Head & Neck Surgery, ‡ is Obstetrics & Gynecology

Virtual Reality Trainer Model

Examining all surgical subdivisions in the various years of training, 10% (9/88) reported experience with virtual reality trainers; 3% (3/88) used it two to three times per year; 3% (3/88) used it monthly, 2% (2/88) used it weekly, and only 1% (1/88) of the population reported more than once daily use. Of all surgical disciplines, ophthalmology residents reported the most frequent use of this teaching method. Evaluating the frequency of use by year of residency training, 5% (1/19), 2% (2/17), 10% (2/22), 7% (1/14), 27% (3/11) of participating residents in first, second, third, fourth, fifth years respectively had experience with virtual reality

TABLE 2 CHARACTERISTICS OF SURGICAL SIMULATORS REPORTED AS MOST AND LEAST LIKED: A) BOX TRAINER MODEL; B) VIRTUAL REALITY TRAINER; C) SIMULATED PATIENT MODEL

a) Box Trainer	
Liked Most (n=29)	**Liked Least (n=18)**
52% - ability to practice	28% - inaccessible
17% - low risk, low pressure environment *"…dedicated teaching time so it's a more supportive environment, no hurry, no yelling"*	28% - unrealistic *"still very different from live case"*
14% - realistic	22% - not applicable in surgical specialty
3% - *"it's fun"*	11% - lack instructors
14% - other *"helpful", "readily available", "supervised"*	11% - other *"boring", "lack of supervision"*
b) Virtual Reality Trainer	
Liked Most (n=7)	**Liked Least (n=7)**
71% - realistic	57% - not realistic
14% - able to practice	14% - lack of supervision
14% - demonstration possible *"can have senior[resident] demonstrate on a simulator"*	14% - lack of opportunity to use virtual reality trainers
	14% - stressful
c) Simulated Patient Model	
Liked Most (n=7)	**Liked Least (n=5)**
43% - able to practice	40% - unrealistic *"too artificial"*
29% - realistic	20% - expensive
14% - convenient	20% - unavailable
14% - other *"would really like the chance to try it!"*	20% - lack guidance

trainers, with the sixth and seventh year trainees having no experience with this model (0/4 for year six and 0/1 for year seven). **Figure 2** depicts the time spent using this model and level of teaching effectiveness ranked by both surgical discipline and year of training.

Overall, nine respondents ranked the effectiveness of this method of instruction. The average rated effectiveness for all respondents was as follows: 44% (4/9) strongly agreed; 22% (2/9) agreed; and 33% (3/9) neither agreed nor disagreed. A marked and significant correlation (r_S=0.78; p=0.02) between frequency of exposure and effectiveness was noted in the group of residents using the virtual reality trainers. Six of the 88 residents recorded a total of seven comments on what they liked most regarding virtual reality training models. Seven residents provided seven comments regarding what they liked least regarding virtual reality training models used in surgical skills instruction (**Table 2b**).

Simulated Patient Models

In all surgical subspecialties and years of training 10% (9/88) of respondents reported experience with simulated patient models. Only 8% (7/88) reported using this model two to three times yearly; 1% (1/88) used it monthly; and only 1% (1/88) used simulated patients weekly. Similar to the virtual reality training model, ophthalmology residents used this method more frequently than any other surgical discipline.

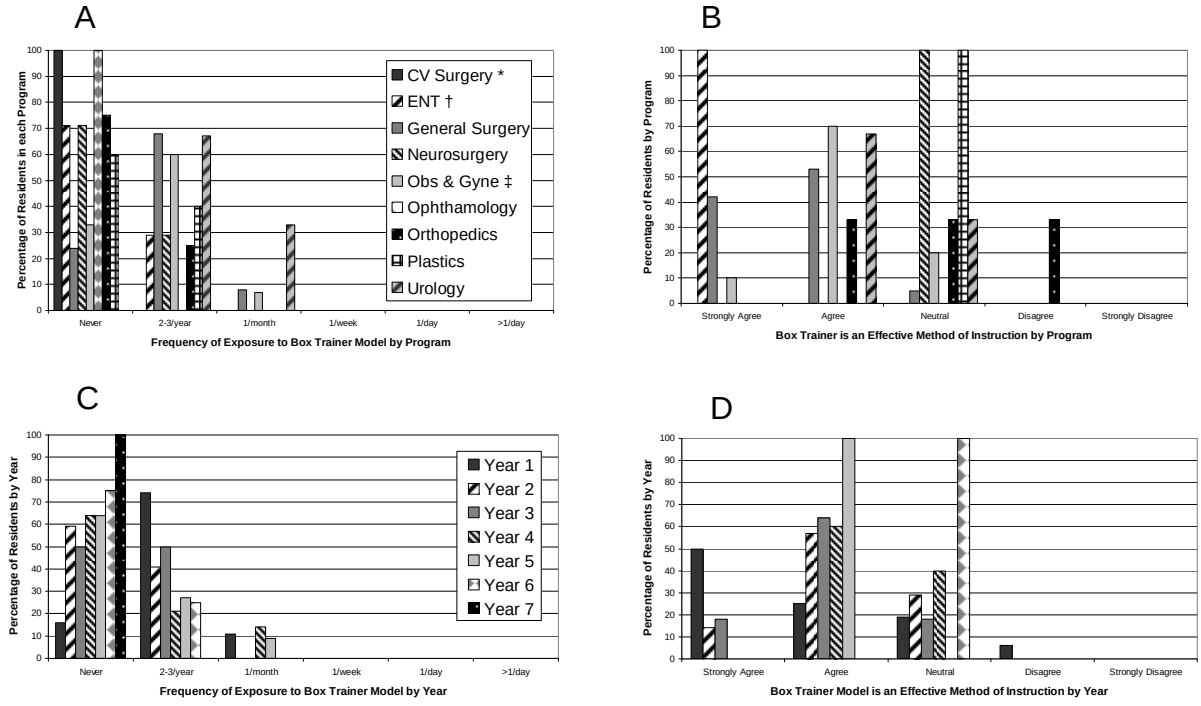

FIGURE 1 BOX TRAINER MODEL – FREQUENCY OF BOX TRAINER USE IN TEACHING SURGICAL SKILLS BY SURGICAL DISCIPLINE (A AND B) AND YEAR OF TRAINING (C AND D) WITH CORRESPONDING RANK OF EFFECTIVENESS. *CV SURGERY IS CARDIOVASCULAR SURGERY, † ENT IS OTOLARYNGOLOGY – HEAD & NECK SURGERY, ‡OBS-GYNE IS OBSTETRICS & GYNECOLOGY

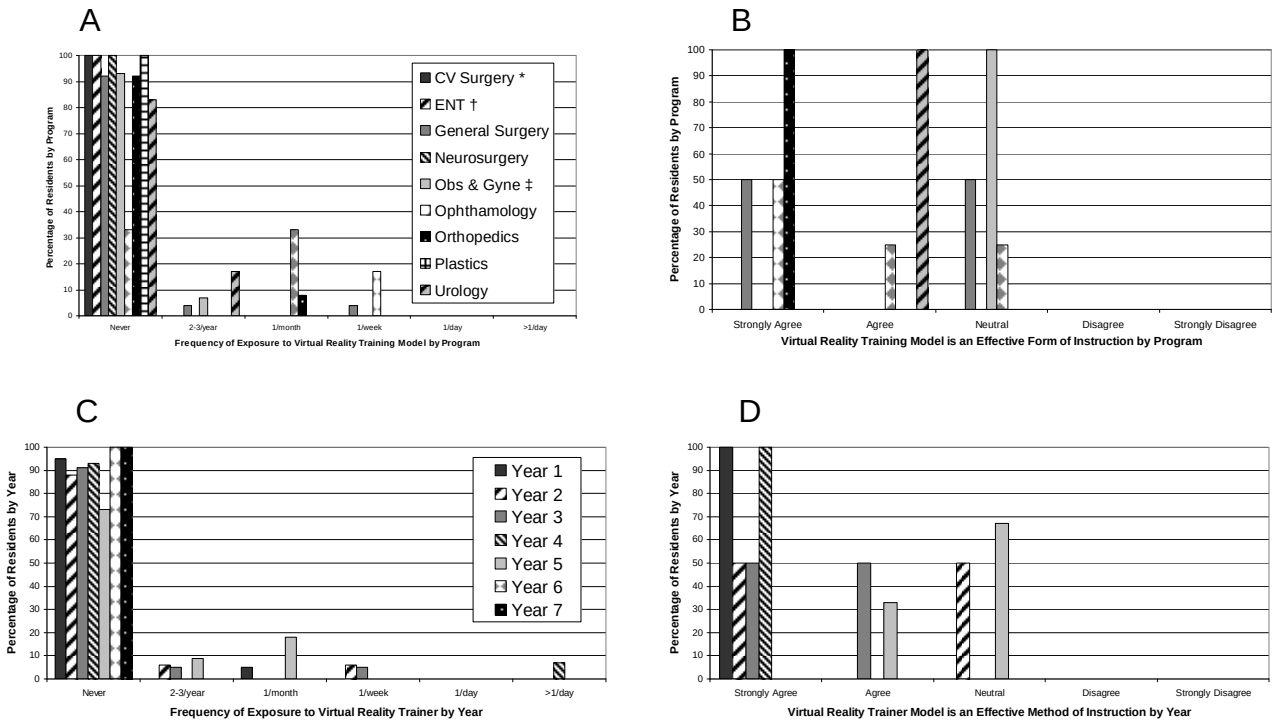

FIGURE 2 VIRTUAL REALITY TRAINER MODEL – FREQUENCY OF VIRTUAL REALITY TRAINER USE IN TEACHING SURGICAL SKILLS BY SURGICAL DISCIPLINE (A AND B) AND YEAR OF TRAINING (C AND D) WITH CORRESPONDING RANK OF EFFECTIVENESS. *CV SURGERY IS CARDIOVASCULAR SURGERY, † ENT IS OTOLARYNGOLOGY – HEAD & NECK SURGERY, ‡OBS-GYNE IS OBSTETRICS & GYNECOLOGY

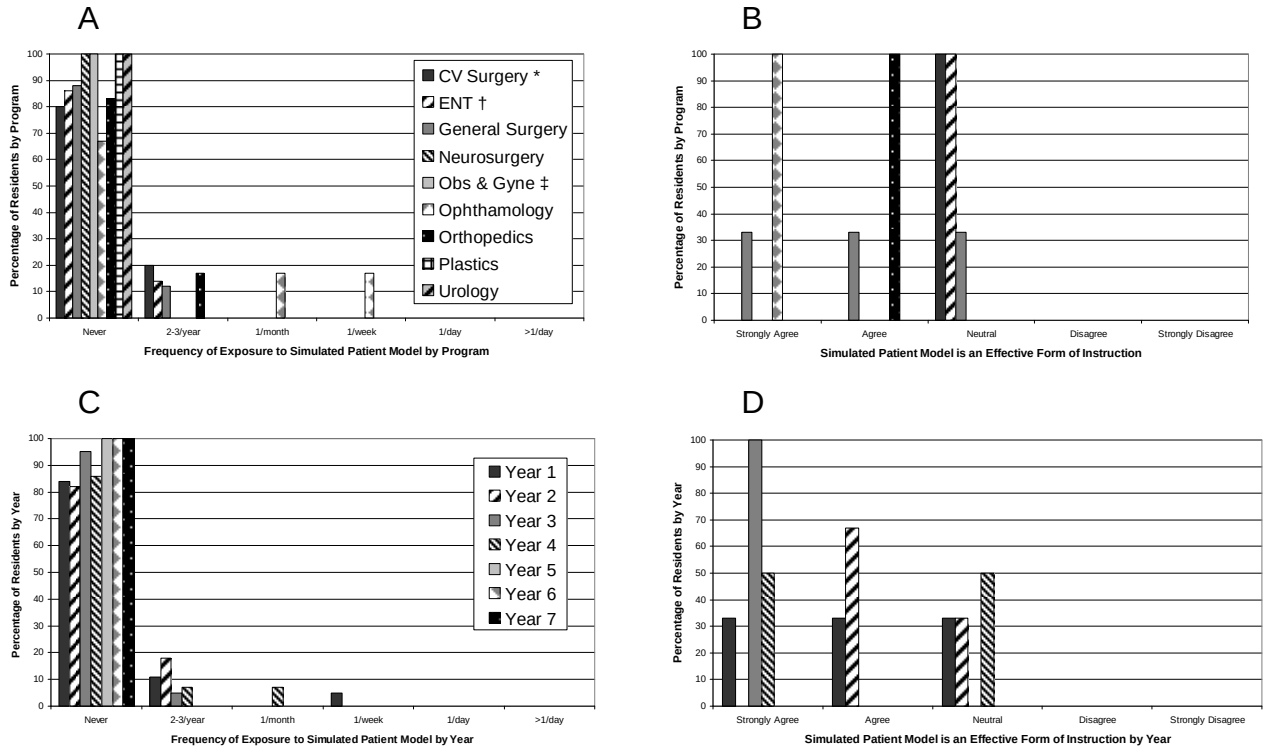

FIGURE 3 SIMULATED PATIENT MODEL – FREQUENCY OF SIMULATED PATIENT MODEL USE IN TEACHING SURGICAL SKILLS BY SURGICAL DISCIPLINE (A AND B) AND YEAR OF TRAINING (C AND D) WITH ASSOCIATED RANK OF EFFECTIVENESS.*CV SURGERY IS CARDIOVASCULAR SURGERY, † ENT IS OTOLARYNGOLOGY – HEAD & NECK SURGERY, ‡OBS-GYNE IS OBSTETRICS & GYNECOLOGY

Eighty-four percent (16/19) of first year residents had not used this method. This experience is similar to the remaining years with 82% (14/17) of second year residents, 95% (21/22) of third year residents, 86% (12/14) of fourth year residents, and 100% (11/11; 4/4; and 1/1) of fifth, sixth, and seventh year residents. **Figure 3** depicts the amount of time spent by trainees and the level of teaching effectiveness ranked both by surgical program and year of training. Overall 9 respondents ranked the effectiveness of simulated patient models. The average rated effectiveness by all respondents was as follows: 33% (3/9) strongly agreed; 33% (3/9) agreed; and 33% (3/9) neither agreed nor disagreed with simulated patient trainer models. A marked degree of correlation (r_S=0.65) between frequency of exposure and effectiveness was found and although there was a trend towards significance, this result was not statistically significant (p=0.06). Six of the 88 residents (6%) recorded a total of seven comments on what they liked most regarding full procedural trainers. Four residents provided five comments regarding what they liked least regarding this model used in surgical education (**Table 2c**).

Discussion

Due to ever expanding surgical techniques and technologies, coupled with restricted hours and access to complex surgical patients, along with the growing concerns of patient litigation, the manner in which surgical trainees are instructed is changing. Alternatives to living patients as teaching models are being sought and implemented in training programs across the nations. Among the alternatives are the surgical simulators and these vary from simple box trainers to sophisticated and costly virtual reality trainers. How prevalent these alternatives are within surgical training programs, however, has not yet been determined.

Upon review of current teaching methodologies at one Canadian academic institution, the use of surgical simulators remained a relatively minor part of surgical education for the majority of surgical disciplines. Only 50% of participating residents at this institution (U of A) reported using box trainers throughout the course of their surgical training. Of all surgical disciplines, interestingly the urology residents used this method of instruction most frequently. In discussion with the Urology Program Director at the U of A, box trainers are readily accessible to residents at all hours as since 2000 there are box trainers located with resident call rooms. This ready access may increase the likelihood of use by the urology residents. Certainly use of box trainers at the U of A furthers the laparoscopic training in keeping with the work of Dechene *et al.* in 2006.[11] This study noted that, of all urologic training programs registered with the American Urologic Association, only 38% of responding residents felt their training in laparoscopic techniques to be "satisfactory". From their study, the investigators called for expanded laparoscopic technical training within urology programs.

Only ten percent of all participating residents used virtual reality trainers or simulated patient models as part of their surgical training. Residents who used these high fidelity models, however, perceived them to be very effective in their instruction. A marked degree of correlation (0.78 and 0.65 with virtual reality trainers and simulated patients respectively) was found between the perceived efficacy of the instructional tool and the amount of time residents employed this tool in their training. Despite the small numbers of residents using this method, this correlation was significant (p = 0.02) for the virtual reality trainers and approaching significance for the simulated patient models (p = 0.06). It is apparent that the more time a resident spent with the surgical simulators, the more effective they felt this teaching method to be.

There also appeared to be a difference in the surgical training model used depending on the year of surgical training. Interestingly, use of the simulated patient models was noted to be directed to the more junior residents. Only one of the thirty (3%) residents in fourth year or above used a simulated patient model in their education to date. The majority of respondents who had tried the highest fidelity model of instruction were in the early years of their surgical education. This finding likely reflects the introduction of the surgical simulators early in surgical residency as traditionally more senior trainees would spend more of their training time in the operating room with patients rather than practicing on alternate surgical models.

In general, the data showed that residents found learning with surgical simulation a desirable situation. It appeared that the ability to practice on multiple occasions in a low pressure learning environment was well received by surgical trainees (**Table 2**). This finding is not overly surprising as the operating room as an educational forum has been previously reported

to be a less than ideal learning environment for junior trainees.[12] The high cost of mistakes to the patient, the rapid and often intense pace, and anxiety provoking environment of the operating room may not be conducive to effective learning. Although alternative models may be the solution to some of these concerns, these are not without their own flaws. For example, the greatest criticism of all surgical simulators studied was the lack of realism. Given the variability of normal and abnormal anatomy presenting in living patients, it is not surprising that even the currently available high fidelity simulators cannot recreate a living model.

Implementing new training techniques into surgical residency programs that promote differentiated instruction is critical to the successful education of competent surgeons. A significant consideration prior to integrating surgical simulation models however, is the cost that can be associated with this. Purchasing these training models can vary greatly in cost, from relatively inexpensive box trainers to expensive high fidelity simulator equipment that can cost hundreds of thousands of dollars. To determine whether a new training model is indeed cost prohibitive, costs of training surgical residents in traditional manners need to be examined. Bridges and Diamond demonstrated in 1999 that the cost associated with training surgical residents in the operating room due to increased surgical time amounted to nearly $48 000 USD per surgical resident per year. In 1999, this amounted to $53 million USD per annum to train surgical residents across the nation.[13] Collectively, this suggests that the implementation of virtual reality trainers may prove to be more cost effective than expected. Tempered with the cost to the patient in the event of any errors, cost to health care in rehabilitation and further treatment, economic cost of lost income of the patient, and the cost of rehabilitating or retraining the health professionals, virtual reality training may have a greater benefit overall.

Although U of A surgical trainees are comparable to other surgical trainees across Canada, data gathered in this study may not fully represent the surgical training models employed in other programs throughout the country. Additionally, there are many different surgical educators involved in training each new surgeon, and it remains unlikely that resident training is uniform across the country. From the study, however, it is evident that the beneficial use of different instructional methods exists within different training rotations, disciplines of surgery, and years of training at this institution. It would therefore seem reasonable to presume that programs from other institutions could vary as well to their benefit. Despite these variations, the general principles of surgical skill instruction are similar across not only regions but also nations and information garnered in this study may be useful to other institutions involved in the training of future surgeons.

Conclusion

Modern surgical training remains a complex process of both cognitive and psychomotor skills training. Use of surgical simulators in this process is expanding as new technologies become available and the drive to practice outside the surgical suite persists. This study examined the use and perceived effectiveness of three surgical simulation models employed in surgical resident training at a Canadian medical college. Our research showed that while surgical simulation models are just being introduced into the training programs, residents who have the opportunity to use these models perceive them to be effective in surgical skills transmission. As more experience and understanding is gained in surgical education, enhanced teaching methods will ultimately produce better skilled and competent surgeons, the goal of every surgical training program.

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